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VERTICILLIUM WILT OF ALFALFA

A Destructive Disease in Britain and Europe not yet Observed in the United States

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During the past several years research investigators and plant quarantine officials in the United States have become increasingly concerned about a destructive disease of alfalfa (Medicago sativa L.) incited by a strain or strains of the fungus Verticillium albo-atrum Reinke and Berth. that is causing serious losses in Britain and parts of Europe. According to Engelhard (10) [2], the only report in the United States of Verticillium infection in a member of the genus Medicago was on bur clover (M. hispida Gaertn.) in California (24, 25). Rudolph (25) succeeded in artificially infecting bur clover by transplanting healthy young plants to soil infested with Verticillium isolates from several unrelated hosts. The inoculated plants developed a dull unhealthy color and remained stunted. A Verticillium sp. was reisolated from several aboveground stems that were cultured. On the basis of field and greenhouse tests, Smith (26) recently reported that alfalfa was highly resistant to Verticillium strains attacking cotton.

The ubiquitous distribution of Verticillium albo-atrum in soils of the United States has been known for many years from the broad range of hosts infected. Consequently, no great concern was felt about European reports of Verticillium wilt in alfalfa until the uniqueness of the strain or strains of V. albo-atrum attacking alfalfa was established principally by I. Isaac's investigations in England (14, 15).

Research conducted by British investigators has shown that the fungus can be carried with the seed in diseased fragments of plant tissue and that seedborne dissemination of the fungus can be prevented by treating the seed with a suitable fungicide. Substantial amounts of alfalfa seed are being imported into the United States for breeding, multiplication, and forage purposes. Seed sometimes comes from countries where the disease is known to occur. Furthermore, varieties of alfalfa commonly grown in the United States are susceptible to the disease when grown in naturally infested soil in Europe.

Since alfalfa valued in excess of 1.2 billion dollars is the principal legume grown for hay on about 30 million acres in the United States, introduction of alfalfa Verticillium wilt would be disastrous to farmers in areas where environmental conditions favor the disease. To protect alfalfa growers in the United States, it was recommended that all alfalfa seed originating outside the United States be treated with an effective fungicide to ensure its freedom from Verticillium wilt infection. Plant quarantine

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2/ Figures in parentheses refer to Literature Cited at end of this report.

regulations were therefore amended effective August 19, 1961, specifying that alfalfa seed may be imported only under permit and that it must be treated upon arrival with a recommended fungicide 3/. It is hoped that these measures will delay or possibly prevent entry of this destructive pathogen into the United States until resistant lines of alfalfa can be found.

Most of the research on the disease to date has been done by British and European scientists. To familiarize interested workers in the United States with the problem, the available information regarding Verticillium wilt of alfalfa is presented herewith.

DISTRIBUTION AND IMPORTANCE

Wilt of alfalfa incited by V. albo-atrum was reported first from Germany by Richter and Klinkowski in 1938 (22, 23). No further mention of Verticillium wilt appeared in German reports dealing with alfalfa diseases until 1957 when Kiessig and Haller-Kiessig (17) compared the symptoms induced in alfalfa by V. albo-atrum infection with those produced by Fusarium sp. and Corynebacterium insidiosum (McCulloch) Jensen. Wagner (30) cultured more than 700 alfalfa root fragments on nutrient agar and found that nearly 7 percent yielded Verticillium albo-atrum. In a survey of alfalfa in Germany and Switzerland during the period 1954 to 1956, Weltzien (31) found that incidence of Verticillium wilt infection varied from 5 to 100 percent, with averages of 50 percent. It was concluded that wilt infection during this period caused almost total loss of the seed crop in parts of Germany. According to Weltzien (31) it is now uneconomical to maintain an alfalfa crop for more than 3 years.

Verticillium albo-atrum was reported as responsible for unthrifty growth of alfalfa in Denmark in 1944 and 1945. The unthrifty condition had been under investigation since 1938 and V. albo-atrum was isolated from wilted alfalfa plants in 1941 and 1944 when destructive outbreaks of the disease occurred causing serious losses (1, 13, 28). In 1945, severe attacks of Verticillium wilt were reported from several locations in Denmark. In some fields plants were destroyed in large patches. On one farm the disease was found in alfalfa plants derived from seed of foreign origin but alfalfa from native-grown seed was free of infection (2). Verticillium wilt of alfalfa has been reported from Denmark nearly every year to the present. In some years the disease is serious, destroying large areas in fields or even entire stands in a week or two during hot weather (29). In other years, Verticillium wilt occurs sporadically and causes minor loss (5, 7).

Verticillium wilt of alfalfa occurred in Holland in 1950. The fungus was isolated from discolored vascular tissue of diseased alfalfa plants in a 3-year-old stand (3). According to Kort and van Rheenen (18), the disease

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3/ The treatment presently recommended is 8 ounces of 50 percent thiram or equivalent per 100 pounds of seed or other chemical or method found to be substantially as effective in eliminating infection.

is destructive to alfalfa in the province of Zeeland where many farmers cannot maintain stands longer than 2 years.

V. albo-atrum was reported in 1953 as the causal agent of alfalfa dying in Scotland and East Anglia (20). In 1954, 1955, and 1956, Verticillium-wilted alfalfa was found in various parts of England and in one locality in Wales. The causal organism of wilt in plants from 28 locations was identified as V. albo-atrum, but a wilted specimen from Cambridge yielded for the first time cultures of V. dahliae Kleb. Only an occasional plant in a field was infected, so that at present wilt caused by V. dahliae is of little economic importance (14).

Since it was first observed, Verticillium wilt has greatly increased in distribution and severity in Britain and is causing serious losses in all alfalfa fields (14, 15, 16). Damage by the disease to alfalfa is caused not only from mortality of plants but also by wilting and desiccation of foliage which affects both the quality and quantity of forage. Previously, alfalfa fields in Britain were usually maintained for at least 4 years, but crops affected by Verticillium wilt frequently have no value at the end of the third harvest year and are consequently plowed up. Evidence is now accumulating to show that harvest even after the second year is often unprofitable. In many fields the incidence of infection increased from approximately 1 percent in the first harvest year to over 50 percent in the third, when the crop was virtually worthless. Alfalfa sown on previously affected land shows quicker onset of disease.

In 1957 the disease was reported for the first time on alfalfa from the Anconetano and Catonese areas of Italy (12). According to the report V. albo-atrum in its sclerotic form, V. dahliae, was isolated from diseased roots.

V. albo-atrum was apparently isolated in the summer of 1950 from diseased alfalfa in nurseries at Coulommiers, France. Artificial inoculation tests with isolates of the fungus resulted in typical Verticillium wilt infection (4) 4/.

Apparently Verticillium wilt of alfalfa has not been found in the USSR. Gerasimova and Minajeva (11) do not list Verticillium as a pathogen of alfalfa. According to Parker (21), Soloveva and Polyarkova (27) observed that alfalfa is resistant to Verticillium strains attacking cotton.

Verticillium wilt of alfalfa probably occurs elsewhere but the disease may not have been recognized or reports have not come to the author's attention.

4/ Shortly before this manuscript was published, additional information was received in correspondence from Prof. G. Viennot-Bourgin, Institut National Agronomique, Paris, and Director E. Vitrac, Tourneur Freres, Coulommiers, France. Verticillium wilt is relatively widespread in France and selection for resistance is being pursued. Prof. Viennot-Bourgin kindly called the author's attention to the following reference in which Verticillium wilt of alfalfa is discussed: Courtillot, M. 1961. Les Maladies des legumineuses fourrageres. Producteur Agricole Francais No. 44 (March) pp. 3-16.

SYMPTOMS

Identical wilt symptoms are incited in alfalfa by V. albo-atrum and V. dahliae (15, 16). Symptoms can be readily recognized in the field from May to September (figures 1 and 2). In late autumn symptoms are more difficult to distinguish because of similarity to natural die-back in healthy plants.

Figure 1.--Healthy alfalfa plant (A) and Verticillium wilt-infected plant (B), showing stunting, permanent wilting, and "flagging" of upper leaves on some shoots. (Courtesy of Dr. A. Zaleski, National Institute of Agricultural Botany, Cambridge, and the Editor of Plant Pathology.)

Figure 2.--Field of Verticillium wilt-infected alfalfa near Robaakegaard, Denmark, showing numerous wilted plants and patches where alfalfa has been killed by the disease.

In first-year alfalfa stands, wilt usually appears in isolated patches of one to several plants but in second and third year stands, the disease occurs either in large irregular patches or frequently in strips paralleling rows of plants. The distribution of wilted plants in a field is probably correlated with the methods of dissemination of the fungus. Frequently at the end of the second and invariably at the end of the third year, the infected alfalfa crop is worthless as fodder. As the disease weakens plants they are less able to compete with weeds and stands are further decimated by weed competition.

Earliest symptoms of wilt in affected fields occur when the alfalfa is less than 1 foot high. During the spring growth of the first season isolated plants appear stunted and pale yellow with flaccid shoots. Diseased plants show "flagging" of upper leaves during warmer periods of the day with some recovery as temperatures drop toward evening. Occasionally, during hot summer days, all the aerial parts of infected plants wilt and no recovery occurs. As the disease progresses, leafy shoots show more permanent symptoms, affected leaves become pale yellow, desiccated, and are easily detached, leading to rapid defoliation. After each cutting, new, apparently

healthy shoots develop from the crown region of diseased plants but this recovery is only temporary because the new shoots quickly develop wilt symptoms (14, 16).

Although Richter and Klinkowski (22) stated that no external symptoms of the fungus occurred on diseased stems, Isaac (14, 15) found that the basal 2 to 6 inches of infected stems, even when not completely dead, are frequently covered by Verticillium conidiophores giving a superficial grayish appearance. When these stems eventually die the basal region becomes blackened, due to the formation in the outer cortex and epidermis of either the dark resting-mycelium of V. albo-atrum or the black microsclerotia of V. dahliae.

Weltzien (31) distinguished several kinds of symptoms on wilted plants in Germany. In one kind of infection the shoots make poor growth and exhibit marked shortening of the internodes. The leaves, particularly the upper ones, are mostly small and narrow, remain folded about the midrib, point somewhat stiffly upward, and usually dry out from the tips and die. A second type of symptom is observed in which the green leaves unfold normally and then curl upward and inward in a slightly spiral fashion after which they wither and fall. There is also a third symptom frequently seen in which the lower leaves in particular turn yellow and fall. Later, conidial fructifications form on the dead stems giving a powdery, grayish appearance.

There are generally no external symptoms of the disease on the roots. In transverse section, typical dark-brown discoloration of the xylem tissues, characteristic of Verticillium infection, sometimes extends to adjacent sclerenchyma cells. Discoloration is due partly to deposition of a gumlike material in the xylem vessels and tracheids and partly to a browning of the walls. Although Noble, et al (20) stated that discoloration was confined to the more central parts of the woody cylinder, Isaac (14) observed it throughout the xylem. In a completely wilted plant, discoloration can be traced from small lateral rootlets through the main root up into the stems to the apices, occasionally into the leaf-petioles and quite frequently into the pedicels of the flowers. The fungus can be isolated from all of these regions. Fungal invasion is confined in the initial stages to vessels and tracheids of the xylem, the amount of mycelium varying from a few scattered hyphae to dense bundles. Tyloses, common in many hosts attacked by these two Verticillium species are seen only infrequently. When the shoots are nearly dead the pathogen grows out transversely from the vessels and tracheids, passing through the pits, generally by way of the parenchymatous wood rays, toward the cortex. After invasion of the cortex, superficial conidiophores develop, but these sporulating structures are never seen in internal tissues. When the stem dies the hyphae in the wood rays and cortex become black and carbonized to form either typical, black, resting-mycelium of V. albo-atrum or black microsclerotia of V. dahliae. Verticillium has been isolated from roots, stems, leaves, peduncles, pedicels, and even fruit walls of diseased plants, but never, despite many attempts, from seeds (14).

Observations by Zaleski (32) on strains and varieties of alfalfa in England showed that earlier strains, which perhaps owing to their advanced stage of maturity showed worse infection at the time of cutting than later strains, seemed to recover much better from symptoms and grew quickly away from the fungus, thus sustaining less damage than a late strain. There was

no great variation between strains in severity of disease but high mortality in the Grimm variety was striking.

MODE OF INFECTION

Outbreaks of the disease have been observed in alfalfa fields during their first year of growth on land where no alfalfa had been cultivated in living memory and where previous crops had been grasses, clovers, or cereals which, so far as is known, are mostly resistant to attack by Verticillium spp.

In England young alfalfa seedlings growing in compost in seed trays were occasionally seen to wilt and V. albo-atrum was isolated from them (14). Handpicked seeds, entirely free from any particles of pod or pedicel from diseased plants, were sown in compost and germinated, producing only healthy plants. Surface-sterilized alfalfa seeds sown in pots of soil to which chopped up pods and pedicels collected from diseased plants had been added, developed wilt symptoms. V. albo-atrum was isolated from the wilted seedlings. From this, it was concluded that pieces of pods and pedicels harvested from diseased alfalfa plants may cause infection in healthy plants. When an infected consignment of alfalfa seed was sifted in the laboratory, pieces of pods, soil, unidentifiable material and other foreign matter were obtained. When this was placed on moist filter-paper in petri dishes, V. albo-atrum was isolated from fragments of plant material. Thus, V. albo-atrum can be carried with the seed in or on foreign plant material, probably in pieces of pods and/or pedicels which have been broken in harvesting and threshing the seed. This probably explains the occurrence of wilt in alfalfa plants growing in soil which had not been sown with alfalfa for many years, and also the outbreak of the disease in seedlings grown in sterilized soil. Any fragmentary plant material containing Verticillium sp. when kept under moist conditions, becomes covered by conidiophores bearing enormous numbers of spores and may affect spread of the disease with the seed. If seed is contaminated with such infected plant material and is stored under damp conditions, it is conceivable that not only would the spores of the pathogen develop in proximity to the seed, but they might also adhere to the seedcoat and so bring about spread of infection.

Once the disease appears in a crop of alfalfa its subsequent rapid spread is due to two main agents of dissemination, spores and fragments of infected stems and leaves. Spore dispersal is induced by air currents and mowing since the fungus grows out from the xylem elements at the base of the alfalfa stem to form conidiophores. A mower may also distribute infected but nonsporing fragments of diseased stems to initiate new infections. Pieces of diseased sporing or nonsporing plant tissue are dispersed during harvesting, particularly where the cut crop is blown into a trailer, and fresh centers of infection are initiated by the fragments. In many affected fields, particularly where the initial source of infection did not come with the seed, wilted plants are at first more frequent near entrances and headlands that in the central portion, the disease obviously being brought in by machinery. Spread inwards occurs as infected stems, leaves, and spores of the fungus are carried into the crop during each harvesting operation. Alfalfa plants examined in the field 3 to 4 weeks after cutting showed that some plants had become recently infected in the crown which showed typical discoloration and yielded cultures of V. albo-atrum although the roots below

were healthy. When alfalfa plants were cut back to approximately 3 to 4 inches above soil level and inoculated on the cut crown with spore suspensions of V. albo-atrum and pieces of diseased stem bearing no conidia, plants became infected in 5 to 6 weeks. In wilted specimens discoloration had spread downward from the crown into the main rootstock for varying distances, but never into lateral rootlets. V. albo-atrum was reisolated from the diseased plants (15).

The possibility of wind-blown spores causing infection was investigated by Davies and Isaac (9), who placed petri dishes of Dox's agar approximately 2 feet above a stand of alfalfa infected with Verticillium wilt. The results indicated that the number of spores of V. albo-atrum in and above infected stands is sufficiently high to suggest that spread of the disease in alfalfa may occur by means of wind-blown spores.

It is also possible that limited spread of the disease may occur by root contact or by emergence of the pathogen from roots of infected plants into the soil. Cultures of V. albo-atrum were isolated from soil surrounding wilted alfalfa plants, the concentration of the fungus becoming progressively greater the nearer the host was to death. Roots of neighboring healthy plants growing into this contaminated soil could easily become infected (14).

The above results demonstrate that the pathogen is not truly seedborne but is introduced into new areas on fragments of plant tissue carried with the seed. Following the appearance of isolated infected plants, the disease spreads rapidly through the dissemination of spores and by contact of these fragments of diseased tissues with wounded surfaces.

ENVIRONMENTAL FACTORS

V. albo-atrum causes wilt under all soil conditions tested, whereas V. dahliae is virulently pathogenic only to plants in soils treated with superphosphate, its effects being otherwise negligible (14). Onset of wilt is usually far more rapid with V. albo-atrum than with V. dahliae, but the subsequent progress and severity of attack are similar for the two pathogens. In soils rich in potash, infection by V. albo-atrum causes development of symptoms in 2 to 3 weeks. Wilted plants in such soil quickly form new lateral shoots in which disease symptoms soon appear, followed by death of the plants. When vigorous alfalfa growth occurs in soils supplied with heavy applications of "hoof and horn" preparation, wilt caused by V. albo-atrum develops in 3 to 4 weeks. In stunted plants such as occur in soils rich in ammonium sulfate or deficient in one of the essential nutrients, disease symptoms are much delayed. The more vigorous the growth of alfalfa the more rapid is the onset of wilt and the sooner will superficial conidiophores appear, resulting in rapid spread of the disease throughout the crop.

In a survey conducted in Holland in 1957 (18), data was collected to determine the effect of soil type, preceding crops, green manuring, manuring with stable manure, pH, soil structure, and weeds on incidence of Verticillium wilt of alfalfa. No correlation between these factors and the severity of attack by Verticillium could be proved except on heavy soils the disease was less severe than on lighter soils.

Results of experiments in Germany (8) suggest that molybdenum and possibly boron deficiencies in the soil may increase susceptibility of alfalfa to infection by Verticillium sp.

HOST RANGE

Between 130 and 140 varieties and/or species of alfalfa were tested in England against V. albo-atrum isolates with the following provisional results (16).

Susceptible

(a) All commercial varieties cultivated in northern Europe and probably originating from Medicago sativa.

(b) Hybrids of M. sativa and M. falcata L.

(c) Inbred and polycross progenies originating from these North European varieties.

(d) Progenies of crossing wild Persian and British types with cultivated alfalfa.

(e) Persian and Turkish varieties.

(f) Progenies originating from South European and Mediterranean alfalfa once inbred.

(g) Most Russian varieties.

Resistant

(a) Under experimental conditions, varieties of alfalfa found in North Africa (M. sativa var. gaetula Urb.) and some Russian varieties of M. sativa have shown a certain degree of resistance.

In artificial inoculation tests made by Isaac (14, 15) and Isaac and Lloyd (16), V. albo-atrum and V. dahliae from alfalfa failed to infect seedlings of red clover (Trifolium pratense L.) varieties or sainfoin (Onobrychis viciifolia Scop.). V. albo-atrum from alfalfa was mildly pathogenic to hop (Humulus lupulus L.), potato (Solanum tuberosum L.), tomato (Lycopersicon esculentum Mill.), and Antirrhinum grandiflorus [probably A. majus var grandiflorum Hort (Boom)]. V. dahliae was mildly pathogenic to potato and tomato, but failed to infect the Antirrhinum species and hop. The incidence of wilt in tomato was fairly high but symptoms were mild and an apparently normal crop of fruit was obtained.

The inability of alfalfa isolates of Verticillium to cause severe wilt in the Antirrhinum species is surprising since all other strains of

V. albo-atrum and V. dahliae tested on this host have been virulently pathogenic which emphasizes the uniqueness of the alfalfa strains. Alfalfa seedlings inoculated with isolates of V. albo-atrum and V. dahliae from sainfoin, hop, tomato, cucumber (Cucumis sativus L.), strawberry (Fragaria x ananassa Duchesne), potato, Antirrhinum sp., and lupine (Lupinus spp.), respectively, were not wilted. Four isolates of V. albo-atrum and one isolate of V. dahliae from alfalfa were tested against 3-month old Du Puits alfalfa seedlings. For comparison a similar series of alfalfa seedlings were tested in soils infected by recent isolates of V. albo-atrum from potato, tomato, and hop. A further series was inoculated with recent isolates of V. dahliae from brussels sprouts (Brassica oleracea L. var. gemmifera Zenker), Antirrhinum sp., and tomato. The 4 isolates of V. albo-atrum from alfalfa induced wilt symptoms in alfalfa seedlings within 4 weeks. Seven weeks elapsed before symptoms occurred in plants inoculated with V. dahliae from alfalfa. All controls and all alfalfa plants in contact with the other 6 isolates remained healthy. Isolations from all plants in infected soil were positive where wilt had occurred, but no isolate was obtained from apparently healthy plants. Results indicated that the 4 isolates of V. albo-atrum from alfalfa and V. dahliae are pathogenic to Du Puits alfalfa, and that the latter appears to be a milder pathogen than any of the other 4. It appears that the isolates of V. albo-atrum and V. dahliae from alfalfa are distinctive strains differing in their range of pathogenicity from those affecting hop, potato, brussels sprouts, Antirrhinum sp., and tomato.

Verticillium and other species of fungi were isolated from 50 different species of weeds in Holland (18). V. albo-atrum from Capsella bursa-pastoris (L.) Medic. and Plantago major L. and V. lecanii (Zimm.) Viegas from P. major, along with Verticillium from alfalfa were the only isolates that produced wilting of leaves and stems when alfalfa plants were artificially inoculated through the roots, stems, and cut portions of plants. No infection was obtained with V. dahliae.

Since potato is mildly infected by Verticillium isolates from alfalfa, cultivation of potatoes following alfalfa is discouraged because the potato crop is likely to increase the reservoir of inoculum. Sainfoin and red clover have both been shown to be resistant to the alfalfa pathogen and may be grown in areas most severely affected by Verticillium wilt (16).

CONTROL

The most important control measures include: Elimination of the fungus carried in fragments of diseased tissue, soil, etc., harvested with the seed and selection of resistant strains of alfalfa. A more immediate control measure in infested areas is the prevention of spread of the fungus from field to field. This can be accomplished through machine disinfection and cutting healthy crops first (14).

Forage loss can be reduced by proper management since severe wilting and dying of foliage occurs as diseased plants mature. Alfalfa should be cut early in the flower-bud stage so that the fungus will have less opportunity to cause loss (32).

The effect of seed fungicides, both on spores carried on the seed surface and on infected material mixed with alfalfa seed, was studied by Isaac and Lloyd (16). Fungicides tested were Agrosan-GN, containing as its toxic ingredient 1 percent mercury, and Fernasan, containing 5 percent 5/ thiram. The results indicated that viability of spores carried on the surface of seeds was markedly reduced by both Agrosan-GN and Fernasan; the latter being lethal to all the spores at a concentration of 1 percent weight-to-weight. Results also indicated that both Agrosan-GN and Fernasan treatments were successful in preventing germination and sporulation of inoculum carried in infected material when it was mixed in a ratio of 1:3 with alfalfa seed, and that the 1 percent weight-to-weight dosages of both fungicides were effective when the weight of infected material was equal to that of the seeds. The proportion of infected material contained with the seed in this experiment was far in excess of foreign debris normally found in any consignment of seed. Data obtained over a period of 6 months showed that neither Agrosan-GN nor Fernasan, in concentrations of 0.2, 0.5, and 1 percent weight-to-weight, significantly affected viability of alfalfa seed but that they effectively reduced the incidence of *Verticillium* infection on the seed tested.

Good nodulation occurred in all plants grown from seed inoculated with Rhizobium bacteria in the seed treatment test. Even the highest concentrations of Agrosan-GN and Fernasan did not prevent activity of nodule bacteria. The conclusion to be drawn from these results is that seed treatment with fungicides comparable to Agrosan-GN or Fernasan would be useful to prevent introduction of *Verticillium* wilt of alfalfa into new areas by eliminating the fungus from infected materials carried with the seed (16).

Observations on varietal resistance to *Verticillium* wilt in alfalfa suggest that all commonly grown varieties are susceptible to the disease (6). However, some varieties of alfalfa from the U.S.S.R. and *M. sativa* var. *gaetula* from North Africa are possible sources of resistance.

Field trials conducted in Germany with varieties of alfalfa yielded differences in reaction to infection with *V. albo-atrum* (19). The variety Pegaur which came from the cross *Medicago sativa* x *M. falcata*, was apparently immune, producing a good stand in the third year of cultivation, whereas other varieties were in poor condition. The apparent immunity of Pegaur may have been the result of its good capacity for growth and regeneration. However, the variety is rather slow-growing in the seedling stage.

DISCUSSION

Verticillium albo-atrum is a destructive pathogen of many important

5/ Isaac (15) and Isaac & Lloyd (16) list the active ingredient of Fernasan as 5 percent thiram. This was erroneous since officials of Plant Protection Ltd. and Dr. Isaac provided the information in correspondence that the active ingredient in Fernasan A, which was presumably used, is 50 percent thiram. No fungicide containing 5 percent thiram is listed under the trade name "Fernasan."

cultivated hosts. The strain or strains of the fungus seriously damaging alfalfa varieties in Britain and Europe are also pathogenic to improved alfalfa varieties presently grown in the United States. Furthermore, the disease in Europe is now known to occur in a broad latitude from Italy to Denmark. The environmental conditions within this latitude are essentially duplicated in many of the most important alfalfa-growing regions of the United States and Canada. Thus, the importance of Verticillium wilt to alfalfa growers in the United States can hardly be overemphasized.

Where and how the strain or strains of V. albo-atrum attacking alfalfa originated are questions that remain unanswered. Strains of the fungus attacking certain weed hosts are apparently capable of infecting alfalfa and may offer a possible explanation. The same weed hosts are commonly found in or near alfalfa fields in the United States but no Verticillium infection has so far been reported on them.

Dissemination of the fungus with the seed probably accounts for the rapid and widespread distribution of the disease in Britain and Europe. Treating seed should aid in preventing or delaying appearance of the disease in new fields or in countries now free of the disease. The similarity of symptoms produced in alfalfa by Verticillium wilt with those incited by other crown and root pathogens suggests that wilted plants should be carefully examined to ensure that infection is not caused by a Verticillium sp.

Since it would be hazardous to conduct research in the U. S. with strains of Verticillium sp. infectious to alfalfa, we are presently dependent on British and European investigators for information about the disease and for devising control measures. It is hoped that adequate sources of resistance will be found and incorporated into desirable varieties. It is also hoped that information will be obtained regarding the effect of various crop rotations on longevity of the fungus in the soil, effect of management practices on reducing damage from the disease, and practicability of chemical soil treatments to eliminate Verticillium wilt infection.

In the meantime, should Verticillium wilt appear in localized areas in the U. S., measures to prevent spread of infection and possible eradication of the fungus by soil fumigation would seem to be of utmost importance.

LITERATURE CITED

1. Anonymous. 1945. Plantesygdomme i Danmark 1944. (Plant diseases and pests in Denmark 1944). Tidsskr. for Planteavl 50:(1): 1-76. (English summary)

2. Anonymous. 1947. Plantesygdomme i Danmark 1945. (Plant diseases and pests in Denmark in 1945). Tidsskr. for Planteavl 51: 373-437. (English summary)

3. Anonymous. 1951. Einige Ziekten en Plagen in Cultuurgewassen in 1950 en hun bestrijding. (Some diseases and pests of cultivated crops in 1950 and their control). Versl. Pl. Ziekt. Dienst, Wageningen 118, 120 pp.

4. _____ Note - Sur Le Fletrissement Verticillien De La Luzerne (Verticillium Wilt of Alfalfa). (Translation from a French article unidentified to date with respect to author and journal.)

5. Anonymous. 1957. Plantesygdomme i Danmark 1954. (Plant diseases and pests in Denmark 1954). Tidsskr. for Planteavl 60:553-611. (English summary).

6. Anonymous. 1958. National Institute of Agricultural Botany, Thirty-ninth Report and Accounts.

7. Anonymous. 1960. Plantesygdomme i Danmark 1958. (Plant diseases and pests in Denmark 1958). Tidsskr. for Planteavl 64:737-800. (English summary).

8. Bortels, H. 1941. Ergänzende Mitteilung über die Wirkung von Molybdän-Dungungen auf Luzerne in Feldversuche. Zbl. Bakt. Abt. 2 CIII, 9-11 pp. 129-133. (Abst., Rev. Appl. Mycol. 21:336. 1942).

9. Davies, R. R., and I. Isaac. 1958. Dissemination of Verticillium albo-atrum through the atmosphere. Nature 181:649.

10. Engelhard, Arthur W. 1957. Host index of Verticillium albo-atrum Reinke & Berth. (Including Verticillium dahliae Kleb.) Plant Disease Rptr. Suppl. 244:23-49.

11. Gerasimova, A. I., and O. M. Minajeva. 1960. Pests and diseases of forage grasses. State Publication of Agricultural Literature, Moscow. 359 pp.

12. Grimaldi, A., M. Ribaldi, and A. Panella. 1957. Osservazioni e ricerche sull'erba medica in relazione ad alcuni aspetti del miglioramento e della difesa della cultura. Genetica Agraria IX:49-67. (English summary).

13. Holme Hansen, H. H., Chr. Stapel, and F. Steenbjerg. 1945. Undersogelser af Lucernemarker paa Lolland - Falster. 80 pp. Stifts - Trykkeriet, Nyköbing, F. (Abst., Rev. Appl. Mycol. 24:451-452. 1945.)

14. Isaac, Ivor. 1957. Wilt of lucerne caused by species of Verticillium. Ann. Appl. Biol. 45:550-558.

15. Isaac, Ivor. 1959. Verticillium wilt of lucerne. NAAS quart. Rev. 1959:11(46):75-79.

16. Isaac, I., and A.T.E. Lloyd. 1959. Wilt of lucerne caused by species of Verticillium. II. Seasonal cycle of disease; range of pathogenicity; host-parasite relations; effects of seed dressings. Ann. Appl. Biol. 47: 673-684.

17. Kiessig, R., and Renate Haller-Kiessig. 1957. Beitrag zur Kenntnis einer infektiosen Welkekrankheit der Luzerne. (Verticillium albo-atrum R et. B.). Phytopath. Z. 31:185-222. (Abst., Plant Disease Rptr. Suppl. 256, p. 116, June 15, 1959).

18. Kort, J., and H. A. van Rheenen. 1960. Enkele Waarnemingen Over Het Optreden Van De Verwelkingsziekte Bij Luzerne in Zeeland in 1957. (Some observations on lucerne wilt disease in Zeeland in 1957). Tijdschr. PlZiekt. 1959, 65:147-157. (English summary).

19. Mihatsch, H. 1957. Beitrag zur Kenntnis einer Welkekrankheit der Luzerne unter besonderer Berucksichtigung der Sortenanfalligkeit. (A contribution to knowledge of a wilt disease of lucerne with special reference to varietal susceptibility). NachrBl. dtsch. PflSchDienst., Berl. 13:22-29. (Abst., Rev. Appl. Mycol. 38:753. 1959).

20. Noble, Mary, N. F. Robertson, and W. J. Dowson. 1953. Verticillium wilt of Lucerne in Britain. Plant Pathology 2(1):31-33.

21. Parker, K. G. 1959. Verticillium hadromycosis of deciduous tree fruits. Plant Disease Rptr. Suppl. 255:39-61.

22. Richter, H., and M. Klinkowski. 1938. Wirtelpilz - Welkekrankheit an Luzerne und Esparsette (Erreger: Verticillium albo-atrum Rke. et Berth.) Nachrichtenbl. f. den Deut. Pflanzenschutzdienst 18:57-58. (Abst., Rev. Appl. Mycol. 17:754-755. 1938).

23. Richter, H., and M. Klinkowski. 1941. Welkekrankeit der Luzerne. Landw. Jb. 90:208.

24. Rudolph, B. A. 1926. Now they know - its verticilliosis. Pacific Rural Press: 111:(25): 763, 766.

25. Rudolph, B. A. 1931. Verticillium hadromycosis. Hilgardia 5:197-354.

26. Smith, T. E. 1961. Reaction of alfalfa to Verticillium albo-atrum. Plant Disease Rptr. 45(7):549.

27. Soloveva, Mme A. I., and Mme L. V. Polyarkova. 1940. (Wilt of cotton.) Tashkent Agr. Publ. Dept., Uzbekistan Soviet Republic. 63 pp. (Title and article in Russian). (Abstr., Plant Disease Rptr. Suppl. 255:39-61. 1959).

28. Stapel, Chr. 1945. Kransskimmel - en ny og alvorlig Sygdom i vore lucernemarker. Ugeskrift for Landmaend 90:125-127.

29. Stapel, Chr. 1956. Nogle Lucernesygdomme. (Some lucerne diseases). Landbonyt, June 1956: 7 pp. (Abst., Rev. Appl. Mycol. 36:408. 1957).

30. Wagner, F. 1957. Zum Problem der Luzernewelke auf Grund mykologischer Untersuchung der Wurzeln. (Contribution to the lucerne wilt problem on the basis of a mycological study of the roots). Pflanzenschutz: 9:109-110. (Abst., Rev. Appl. Mycol. 37:101. 1958).

31. Weltzien, H. C. 1957. Untersuchungen uber das Vorkommen der Luzernevertizilliose und weiterer Luzerneerkrankungen in Sudwestdeutschland. (Studies on the occurrence of verticilliosis and other diseases of lucerne in S. W. Germany). NachrBl. dtsch. PflSchDienst (Braunschweig), Stuttgart, 9:42-45. (Abst., Rev. Appl. Mycol. 36:530-531. 1957).

32. Zaleski, A. 1957. Reactions of lucerne strains to Verticillium wilt. Plant Pathology 6:137-142.

Additional information: Hellmers, Ernst. 1961. Kransskimmel eller Verticillium - hadromykose (Verticillium albo-atrum Reinke and Berthold og V. dahliae Klebahn). Horticultura 15(2):19-27.

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